EXPRESS MAIL CERTIFICATE
"EXPRESS MAIL" LABEL No: EL769792895US
Date of Deposit: April 9, 2001
I hereby certify that this paper or fee and any papers referred to as being attached or enclosed are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above, addressed to: BOX PATENT APPLICATION, Assistant Commissioner for Patents, Washington, D.C. 20231.

Dean C. Brehm

APPLICATION FOR

UNITED STATES LETTERS PATENT

FOR

DOUBLE-ENDED GEOPHONE

Inventors: A. L. Hagedoorn
Netherlands

H. A. Laroo
Netherlands

Assignee: Input/Output, Inc.
12300 Charles E. Selecman Dr.
Stafford, Texas 77477-2416

Background of the Invention

This invention relates generally to geophones, and in particular to double-ended geophone structures.

Geophones are devices which sense motion by suspending an inertial reference mass structure from a rigid, fixed supporting structure. Typically, the mass is a coil form suspended by springs in a magnetic field, one spring being attached at each end of the coil form. The springs position the coil form within the magnetic field so that the coil form is centered laterally and along its axis within the magnetic field. The springs also form a suspension system having a predetermined resonant frequency.

Geophones may be used in a variety of applications such as, but not limited to, seismic operations on land, in boreholes, in mines, and under water. The operating principle is the same regardless of the application or environment. In seismic operations, seismic waves are imparted into the earth's crust at or near the earth's surface, and portions of those seismic waves are reflected or refracted from the boundaries of subsurface layers. Geophones are generally arranged in arrays or groups on the earth's surface, and when the reflected or refracted waves encounter a geophone, the coil form, which is suspended between the two springs, tends to remain substantially motionless relative to the geophone housing while the geophone housing and its connected magnetic circuit moves with the earth's surface. The movement of the coil form through a magnetic field causes a voltage to be generated at the output of the geophone. The outputs of the arrays of geophones are recorded in a form that permits

analysis. Skilled interpreters can discern from the analysis the shape of subsurface formations, and the likelihood of finding an accumulation of minerals, such as oil and gas.

In geophones, both ends of the electrical path have to be electrically insulated from each other and the outside case of the geophone. Typical conventional geophones satisfy this requirement by using insulation sleeves, insulation disks, and other similar devices. Such devices complicate the assembly of the geophone. Furthermore, in typical conventional geophones, both of the signal terminals are positioned on the same side of the geophone. This construction further complicates the assembly.

The present invention is directed to overcoming one or more of the limitations of the existing geophones.

Summary of the Invention

According to one aspect of the invention, a geophone is provided that includes a housing, a first terminal, an electrically conductive path having a first end and a second end, a first coil, a second terminal, a second coil, and a magnet. The first terminal is positioned on one side of the housing. The first end of the electrically conductive path is coupled to the first terminal. The first coil is resiliently mounted within the housing and is coupled to the first end of the electrically conductive path. The second terminal is positioned on another side of the housing. The second end of the electrically conductive path is coupled to the second terminal. The second coil is resiliently mounted within the housing and is coupled to the second end of the electrically conductive path. The first

and second coils are electrically connected to complete the electrically conductive path. The magnet is mounted within the housing.

According to another aspect of the present invention, a geophone is provided that includes a housing having a first end and a second end opposite the first end, first and second end plates, first and second end plate supports, first and second magnet supports, a magnet, first and second resilient rings, first and second springs, first and second coils supports, and first and second coils. The first end plate is coupled to the first end of the housing. The second end plate is coupled to the second of the housing. The first end plate support is coupled to the first end plate. The second end plate support is coupled to the second end plate. The first magnet support is coupled to the first end plate support. The second magnet support is coupled to the second end plate support. The magnet is coupled to the first and second magnet supports. The first resilient ring is coupled to the first end plate support. The second resilient ring is coupled to the second end plate support. The first spring is coupled to the first end plate support. The second spring is coupled to the second end plate support. The first coil support is coupled to the first spring. The second coil is coupled to the second spring. The first coil is coupled to the first coil support. The second coil is coupled to the second coil support. The first coil support is rigidly coupled to the second coil support.

According to another aspect of the present invention, a geophone is provided that includes a housing, an electrically conductive terminal on one end of the housing, another electrically conductive terminal on the opposite end of

the housing, a magnet within housing, and at least one coil resiliently mounted within the housing.

According to another aspect of the present invention, a method of electrically insulating a first electrically conductive component from at least one second electrically conductive component within a geophone by treating at least a portion of the surface of the first component to render the portion electrically insulative.

According to another aspect of the present invention, a seismic acquisition system is provided that includes at least one geophone and a controller. Each geophone includes a housing, first and second electrically conductive terminals, first and second coils, and a magnet. The first electrically conductive terminal is positioned on one side of the housing. The first coil is resiliently mounted within the housing and is operably coupled to the first terminal. The second electrically conductive terminal is positioned on another side of the housing. The second coil is resiliently mounted within the housing and is operably coupled to the second terminal. The magnet is mounted within the housing. The controller is operably coupled the geophone.

Brief Description of the Drawings

FIG. 1 is a cross-sectional illustration of a geophone.

FIG. 2 is a schematic illustration of a seismic acquisition system.

Detailed Description of the Illustrative Embodiments

A geophone for use in a seismic acquisition system is provided. The geophone preferably includes a pair of terminals that are positioned on opposite

sides of the geophone housing for providing an electrical connection to the geophone coils. The electrically conductive path within the geophone is preferably provided by conductive end plate supports, resilient springs, and coil supports. The remaining portions of the geophone are preferably electrically isolated from the conductive path by providing at least some of the components with electrically non-conductive surfaces. While illustrated in terms of a specific example of a geophone, the teachings of the present disclosure will have wide application to the design of electrical devices generally wherein conventional electrical isolation using ceramic, paper, plastics, and other materials is improved through the use of appropriate surface treatments to eliminate the need for additional insulation materials.

Referring initially to **FIG. 1**, a preferred embodiment of a geophone **100** includes a housing **102**, a first end plate **104**, a second end plate **106**, a first end seal **108**, a second end seal **110**, a first end plate support **112**, a second end plate support **114**, a first magnet support **116**, a second magnet support **118**, a magnet **119**, a first coil support **120**, a second coil support **122**, a first coil **124**, a second coil **126**, a first resilient ring **128**, a second resilient ring **130**, a first spring **132**, a second ring **134**, a first retaining ring **136**, and second retaining ring **138**.

The housing **102** includes a first end **140** and a second end **142**. The housing **102** preferably has an annular cross-section. The housing **102** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure.

The first end plate **104** is coupled to the first end **140** of the housing **102**. The first end plate **104** is preferably disk-shaped. The first end plate **104** preferably includes an opening **144**. In a preferred embodiment, the opening **144** is centrally positioned and is substantially circular. In a preferred embodiment, the first end plate **104** is coupled to the first end **140** of the housing **102** by a crimped connection **146** in which the first end **140** of the housing **102** is crimped over the first end plate **104**. In a particularly preferred embodiment, the seal **108** is positioned within the crimped connection **146** to provide a water-tight seal.

The first end plate **104** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a particularly preferred embodiment, the surface of the first end plate **104** is electrically non-conductive. In a preferred embodiment, the surface of the first end plate **104** is made non-conductive by the application of a conventional non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, conventional methods may be used to apply a non-conductive layer such as an oxidized layer or anodized layer to the end plate surface. Alternatively, a non-conductive layer is provided using a combination of the application of a non-conductive coating and an anodized layer or an oxidized layer.

The second end plate **106** is coupled to the second end **142** of the housing **102**. The second end plate **106** is preferably disk-shaped. The second

end plate **106** preferably includes an opening **148**. In a preferred embodiment, the opening **148** is centrally positioned and is substantially circular. In a preferred embodiment, the second end plate **106** is coupled to the second end **142** of the housing **102** by a crimped connection **150** in which the second end **142** of the housing **102** is crimped over the second end plate **106**. In a particularly preferred embodiment, the seal **110** is positioned within the crimped connection **150** to provide a water-tight seal.

The second end plate **106** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a particularly preferred embodiment, the surface of the second end plate **106** is electrically non-conductive. In a preferred embodiment, the surface of the second end plate **106** is made non-conductive by the application of a non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, a non-conductive surface is provided through the application of an oxidized layer or anodized layer using conventional methods. Alternatively, a non-conductive coating is provided using a combination of the application of a non-conductive coating and an oxidized layer or anodized layer.

In several alternative embodiments, the first end plate **104** and the second end plate **106** may be fabricated from any number of conventional commercially available non-conductive materials.

The first end seal **108** preferably provides a water tight seal between the first end **140** of the housing **102** and the first end plate **104**. The first end seal

108 may comprise any number of conventional commercially available seals modified in accordance with the teachings of the present disclosure.

The second end seal **110** preferably provides a water-tight seal between the second end **142** of the housing **102** and the second end plate **106**. The second end seal **110** may comprise any number of conventional commercially available seals modified in accordance with the teachings of the present disclosure.

The first end plate support **112** is coupled to the first end plate **104**. In a preferred embodiment, then first end plate support **112** is mounted within the opening **144** in the first end plate **104**. In a preferred embodiment, the first end plate support **112** is centrally positioned within and supported by the edge of the opening **144** in the first end plate **104**.

The first end plate support **112** preferably includes a substantially cylindrical body **152** having a flange **154**, and a female contact **156**. One end of the cylindrical body **152** is mounted within and supported by the edge of the opening **144**. The flange **154** serves to position and support the first end plate support **112** against the first end plate **104**. The other end of the cylindrical body **152** is positioned on the other side of the flange **154** and preferably supports and positions the first magnet support **116**. The female contact **156** preferably is adapted to receive and mate with a male contact (not illustrated) in order to transmit electrical signals. In one embodiment, the female contact is a threaded hole. In several alternative embodiments, the first end plate support is equipped with a male contact or a solder point or a solder patch.

The first end plate support **112** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a particularly preferred embodiment, the surface of the first end plate support **112** is highly electrically conductive. In a preferred embodiment, the surface of the first end plate support **112** is resistant to oxidation. In a particularly preferred embodiment, the surface, or the entire body, of the first end plate support **112** is fabricated from gold.

In an alternative preferred embodiment, the first end plate **104** and the first end plate support **112** are combined into a single element with the outer radial surface of the single element provided with an electrically insulative surface treatment and the inner redial surface of the single elements provided with an electrically conductive surface treatment, which may be electrically connected to a (not shown) electrically conductive part on the outside of this single element, to act as a terminal. In an alternative embodiment, the first end plate **104** and the first end plate support **112** are both made out of an electrically conductive material and are coupled together using an insulative glue or other suitable adhesive.

The second end plate support **114** is coupled to he second end plate **106**. In a preferred embodiment, the second end plate support **114** is mounted within the opening **148** in the second end plate **106**. In a preferred embodiment, the second end plate support **114** is centrally positioned within and supported by the edge of the opening **148** in the second end plate **106**.

The second end plate support **114** preferably includes a substantially cylindrical body **158** having a flange **160**, and a female contact **162**. One end of the cylindrical body **158** is mounted within and supported by the edge of the opening **148**. The flange **160** serves to position and support the second end plate support **114** against the second end plate **106**. The other end of the cylindrical body **158** is positioned on the other side of the flange **160** and preferably supports and positions the first magnet support **118**. The female contact **162** preferably is adapted to receive and mate with a male contact (not illustrated) in order to transmit electrical signals. In one embodiment, the female contact is a threaded hole. In several alternative embodiments, the first end plate support is equipped with a male contact or a solder point or a solder patch.

The second end plate support **114** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a particularly preferred embodiment, the surface of the second end plate support **114** is highly electrically conductive. In a preferred embodiment, the surface of the second end plate support **114** is resistant to oxidation. In a particularly preferred embodiment, the surface, or the entire body, of the second end plate support **114** is fabricated from gold.

In an alternative preferred embodiment, the second end plate and the second end plate support **114** are combined in a single element with the outer radial surface of the single element provided with an electrically insulative surface treatment while the inner radial surface of the single element is provided with an electrically conductive surface treatment, which may be electrically

connected to an electrically conductive part (not shown) on the outside of this single element, to act as a terminal. In an alternative embodiment, the first end plate **104** and the first end plate support **112** are both made out of a electrically conductive material and are coupled together using an insulative glue or other suitable adhesive.

The first magnet support **116** is coupled to and supported by the first end plate support **112**. The first magnet support **116** is further coupled to the magnet **119** and, in combination with the second magnet support **118**, supports the magnet **119**. In a preferred embodiment, the first magnet support **116** comprises a substantially cylindrical body **164** including a first opening **166** and a second opening **168**. In a preferred embodiment, the first magnet support **116** is supported by and mounted upon the cylindrical body **152** of the first end plate support **112**. In a particular preferred embodiment, one end of the cylindrical body **152** of the first end plate support **112** mates with the first opening **166** of the first magnet support **116**. In a preferred embodiment, one end of the magnet **119** mates with the second opening **168** of the first magnet support **116**. In a preferred embodiment, the first and second openings **166** and **168** are centrally positioned within the cylindrical body **164** of the first magnet support **116**.

The first magnet support **116** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a preferred embodiment, the surface of the first magnet support **116** is electrically insulative. In a preferred embodiment, the surface of the first magnet support **116** is made non-conductive by the

application of a non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, a non-conductive surface is provided through the application of an oxidized layer or an anodized layer using conventional methods. Alternatively, a non-conductive coating is provided using a combination of the application of a non-conductive coating and an oxidized layer or an anodized layer.

The second magnet support **118** is coupled to and supported by the second end plate support **114**. The second magnet support **118** is further coupled to the magnet **119** and, in combination with the first magnet support **116**, supports the magnet **119**. In a preferred embodiment, the second magnet support **118** comprises a substantially cylindrical body **170** including a first opening **172** and a second opening **174**. In a preferred embodiment, the second magnet support **118** is supported by and mounted upon the cylindrical body **158** of the second end plate support **114**. In a particularly preferred embodiment, one end of the cylindrical body **158** of the second end plate support **114** mates with the first opening **172** of the second magnet support **118**. In a particularly preferred embodiment, one end of the magnet **119** mates with the second opening **174** of the second magnet support **118**. In a preferred embodiment, the first and second openings **172** and **174** are centrally positioned within the cylindrical body **170** of the second magnet support **118**.

The second magnet support **118** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a preferred embodiment, the surface of

the second magnet support **118** is electrically insulative. In a preferred embodiment, the surface of the second magnet support **118** is made non-conductive by the application of a non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, a non-conductive surface is provided through the application of an oxidized layer using conventional methods. Alternatively, a non-conductive coating is provided using a combination of the application of a non-conductive coating and an oxidized layer or an anodized layer.

The magnet **119** is coupled to and supported by the first and second magnet supports, **116** and **118**. As will be recognized by persons having ordinary skill in the art, the magnet **119** may comprise a single magnet or a stack of magnets. In a preferred embodiment, one end of the magnet **119** mates with the second opening **168** of the first magnet support **116** and the other end of the magnet **119** mates with the second opening **174** of the second magnet support **118**. In an alternative embodiment, the magnet is glued to at least one of the magnet supports with an electrically nonconductive glue.

In a preferred embodiment, the surface of the magnet **119** is electrically non-conductive. In a preferred embodiment, the surface of the magnet **119** is made non-conductive by the application of a non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, a non-conductive surface is provided through the application of an oxidized layer using conventional methods. Alternatively, a

non-conductive coating is provided using a combination of the application of a non-conductive coating and an anodized layer.

The first coil support **120** is coupled to and supported by the first spring **132**. The first coil support **120** is further coupled to and supports the first coil **124**. In a preferred embodiment, the first coil support **120** includes an annular body **176** including an inner slot **178** and a pair of outer flanges, **180** and **182**. In a preferred embodiment, the inner slot **178** receives an outer portion of the first spring **132** and, in conjunction with the first retaining ring **136** mounts the first coil support **120** onto the first spring **132**. In a preferred embodiment, the first coil **124** is mounted upon the surface of the first coil support **120** within the annular region bounded by the pair of outer flanges, **180** and **182**.

In a preferred embodiment, the surface of the first coil support **120** separated from the surface of the housing **102** by an air gap in order to electrically isolate and permit relative motion between the two elements. Likewise, the surface of the first coil support **120** is also preferably separated from the surface of the first magnet support **116** in order to electrically isolate and permit relative motion between the two elements.

The first coil support **120** may be fabricated from any number of conventional commercially available materials modified in accordance with the teachings of the present disclosure. In a preferred embodiment, the surface of the first coil support **120** is made non-conductive by the application of a non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, a non-conductive

coating is provided through the application of an oxidized layer using conventional processes. Alternatively, a non-conductive surface is provided by the application of a combination of a non-conductive coating and an anodized layer. In another embodiment, the coil support **120** is manufactured from an electrically non-conductive material.

The second coil support **122** is coupled to and supported by the second spring **134**. The second coil support **122** is further coupled to and supports the second coil **126**. In a preferred embodiment, the second coil support **122** includes an annular body **184** including an inner slot **186** and a pair of outer flanges, **188** and **190**. In a preferred embodiment, the inner slot **186** receives an outer portion of the second spring **134** and, in conjunction with the second retaining ring **138** mounts the second coil support **122** onto the second spring **134**. In a preferred embodiment, the second coil **126** is mounted upon the surface of the second coil support **122** within the annular region bounded by the pair of outer flanges, **188** and **190**.

In a preferred embodiment, the surface of the second coil support **122** is separated from the surface of the housing **102** by an air gap in order to electrically isolate and permit relative motion between the two elements. Likewise, the surface of the second coil support **122** is also preferably separated from the surface of the second magnet support **118** in order to electrically isolate and permit relative motion between the two elements.

The second coil support **122** may be fabricated from any number of conventional commercially available materials modified in accordance with the

teachings of the present disclosure. In a preferred embodiment, the surface of the second coil support **122** is made non-conductive by the application of a non-conductive coating using conventional processes such as, for example, spray coating, dipcoating, or evaporation coating. Alternatively, a non-conductive coating is provided through the application of an oxidized layer using conventional processes. Alternatively, a non-conductive surface is provided by using a combination of a non-conductive coating and an anodized layer. In another embodiment, the second coil support **122** is manufactured from an electrically non-conductive material.

In a preferred embodiment, the first and second coil supports, **120** and **122**, are electrically insulated from each using conventional methods and apparatus.

The first coil **124** is coupled to and supported by the first coil support **120**. In a preferred embodiment, the first coil **124** is mounted upon the surface of the first coil support **120** within the annular region bounded by the pair of outer flanges, **180** and **182**. The general design, construction and operational features of such coils are otherwise well known to persons having ordinary skill in the art.

The second coil **126** is coupled to and support by the second coil support **122**. In a preferred embodiment, the second coil **126** is mounted upon the surface of the second coil support **122** within the annular region bounded by the pair of outer flanges, **188** and **190**. The general design, construction and operational features of such coils are otherwise well known to persons having ordinary skill in the art.

The first coil **124** and the second coil **126** are electrically connected. The general design, construction and operational features of this connection are otherwise well known to persons having ordinary skill in the art.

The first resilient ring **128** is coupled to and supported by the first end plate support **112**. In a preferred embodiment, the first resilient ring **128** is mounted upon the body **152** of the first end plate support **112** between the flange **154** and the first magnet support **116**. In a particularly preferred embodiment, the first resilient ring **128** is mounted upon the body **152** of the first end plate support **112** between the flange **154** and the first magnet support **116** such that it exerts a retaining force upon the first spring **132**.

The first resilient ring **128** may comprise any number of conventional commercially available resilient rings modified in accordance with the teachings of the present disclosure.

The second resilient ring **130** coupled to and supported by the second end plate support **114**. In a preferred embodiment, the second resilient ring **130** is mounted upon the body **158** of the second end plate support **114** between the flange **160** and the second magnet support **118**. In particularly preferred embodiment, the second resilient ring **130** is mounted upon the body **158** of the second end plate support **114** between the flange **160** and the second magnet support **118** such that it exerts a retaining force upon the second spring **134**.

The second resilient ring **130** may comprise any number of conventional commercially available resilient rings modified in accordance with the teachings of the present disclosure.

The first spring **132** is coupled to the first end plate support **112**. The first spring **132** is also coupled to the first coil support **120**. In this manner, the first spring **132** permits the first coil to move relative to the magnet **119**.

In a preferred embodiment, an outer edge of the first spring **132** is mounted in the inner recess **178** of the first coil support **120** using the first retaining ring **136**. In a preferred embodiment, an inner edge of the first spring **132** is mounted on the first end plate support **112** between the flange **154** and the first magnet support **116**. In a particularly preferred embodiment, the inner edge of the first spring **132** is mounted on the first end plate support **112** between the flange **154** and the first magnet support **116** with the first resilient ring **128** providing a retaining force upon the first spring **132**.

As will be recognized by persons having ordinary skill in the art, the first spring **132** may comprise an inner ring and an outer ring that are connected by one or more resilient arms. The first spring **132** may comprise any number of conventional commercially available resilient rings modified in accordance with the teachings of the present disclosure.

The second spring **134** is coupled to the second end plate support **114**. The second spring **134** is also coupled to the second coil support **122**. In this manner the second spring **134** permits the second coil to move relative to the magnet **119**.

In one embodiment, the first coil support **120** and the second coil support **122** are rigidly connected to form one moving body. The first spring **132** and the second spring **134** support the combined coil supports **120** and **122**, both in the radial in the axial direction, around the magnet.

In a preferred embodiment, an outer edge of the second spring **134** is mounted in the inner recess **186** of the second coil support **122** using the second retaining ring **138**. In a preferred embodiment, an inner edge of the second spring **134** is mounted on the second end plate support **114** between the flange **160** and the second magnet support **118**. In a particularly preferred embodiment, the inner edge of the second spring **134** is mounted on the second end plate support **114** between the flange **160** and the second magnet support **118** with the second resilient ring **130** providing a retaining force upon the second spring **134**.

As will be recognized by persons having ordinary skill in the art, the second spring **134** may comprise an inner ring and an outer ring that are connected by one or more resilient arms. The second spring **134** may comprise any number of conventional commercially available resilient rings modified in accordance with the teachings of the present disclosure.

The first retaining ring **136** is coupled to and mounted upon the first coil support **120**. In a preferred embodiment, the first retaining ring **136** is resiliently mounted within the recess **178** of the first coil support **120**. In this manner, the first retaining ring **136** holds the outer edge of the first spring **132** within the recess **178** of the first coil support.

The first retaining ring **136** may comprise any number of commercially available retaining rings modified in accordance with the teachings of the present disclosure.

The second retaining ring **138** is coupled to and mounted upon the second coil support **122**. In a preferred embodiment, the second retaining ring **138** is resiliently mounted within the recess **186** of the second coil support **122**. In this manner, the second retaining ring holds the outer edge of the second spring **134** within the recess **186** of the second coil support.

The second retaining ring **138** may comprise any number of commercially available retaining rings modified in accordance with the teachings of the present disclosure.

The geophone **100** preferably provides a conductive electrical path that is insulated form the housing **102**, with opposing ends of the electrical path insulated from each other.

In a preferred embodiment of the geophone **100**, one end of the conductive electrical path includes the first end plate support **112**, the first resilient ring **128**, the first spring **132**, the first coil support **120**, and the first coil **124**. The opposing end of the electrical path includes the second coil **126**, the second coil support **122**, the second spring **134**, the second resilient ring **138**, and the second end plate support **114**. The first coil **124** and the second coil **126** are electrically connected to combine the first end of the electrical path with the second, or opposing end, of the electrical path to form one electrical circuit. The electrical path through the magnet supports **116** and **118** and the magnet

119 is prevented by the electrically insulative surfaces of at least one of these elements. The electrical path to the housing **102** is prevented by the electrically insulative surfaces of the end plates of **104** and **106**. In alternative preferred embodiments, the electrically insulative surface treatment is omitted from the first and second magnet support **116** and **118**, the first magnet support **116** and the magnet **119**, the magnet **119** and the second magnet support **118**, the first magnet support **116**, the second magnet support **118**, or the magnet **119**.

In an alternative embodiment, the magnet **119** is divided into an upper portion and a lower portion. The upper portion and the lower portion are mechanically connected. This connection can be direct or with the use of extra rings or bushes. The surface of the magnets, or of one of the magnets, has been modified so that the combination is nonconductive. It is also possible that a ring or bushing, which connect both halves of the magnet, has a nonconductive surface or is made out of a nonconductive material.

In this manner, the geophone **100** is provided with electrical terminals on opposite sides of the housing **102** using a conductive path that is electrically isolated using components having electrically insulative surface treatments. In this manner, the use of conventional insulating rings, bushes, ceramic insulators, glass seals, and similar devices is eliminated or reduced. This results in a geophone design that is simpler to manufacture and more resistant to mechanical shocks and vibration.

In an alternative embodiment, the size of the electrical terminals, in the form of the end plate supports **112** and **114**, may be enlarged to comprise the

totality of end portions of the geophone **100** by appropriate surface treatments in accordance with the teachings of the present disclosure.

Referring to **FIG. 2**, a preferred embodiment of seismic acquisition system **200** will now be described. The seismic acquisition system **200** includes a controller **205** and one or more geophones **210**. The seismic acquisition system **200** is preferably operated in a wellbore **215** to gather seismic data.

The controller **205** is operably coupled to the geophones **210** and is adapted to monitor and/or control the operation of the geophones **210**. The controller **205** may comprise any number of conventional controllers for use in a seismic acquisition system.

The geophones **210** preferably comprise the geophones **100** previously described with reference to **FIG. 1**. The geophones **210** are operably coupled to the controller **205**. In a preferred embodiment, the geophones **210** are operably coupled to the controller **205** using a cabling assembly **220** that includes male contacts that mate with the female contacts of the geophones **210**.

A geophone has been described that includes a housing, first and second terminals, first and second end of the electrically conductive path, first and second coils, and a magnet. The first terminal is positioned on one side of the housing. The first end of the electrically conductive path is coupled to the first terminal. The first coil is resiliently mounted within the housing and is coupled to the first end of the electrically conductive path. The second terminal is positioned on another side of the housing. The second end of the electrically conductive path is coupled to the second terminal. The second coil is resiliently

mounted within the housing and is coupled to the second end of the electrically conductive path. The magnet is mounted within the housing.

In a preferred embodiment, the first and second ends of the conductive path are electrically insulated from each other. In a preferred embodiment, the magnet, the first end of the conductive path, and the second end of the conductive path are electrically insulated from each other. In a preferred embodiment, the housing, the magnet, the first end of the conductive path, and the second end of the conductive path are electrically insulated from each other. In a preferred embodiment, the first end of the conductive path includes a first end plate support, a first spring, and a first coil support. In a preferred embodiment, the second end of the conductive path includes a second end plate support, a second spring, and a second coil support. In a preferred embodiment, the first end of the conductive path includes a first end plate support, a first spring, and a first coil support, and the second end of the conductive path includes a second end plate support, a second spring, and a second coil support. In a preferred embodiment, the geophone further includes a first magnet support coupled to the housing and the magnet, and a second magnet support coupled to the housing and the magnet. In a preferred embodiment, at least a portion of the surface of the magnet is electrically non-conductive. In a preferred embodiment, at least a portion of the surface of the first magnet support is electrically non-conductive. In a preferred embodiment, at least a portion of the surface of the second magnet support is electrically non-conductive. In a preferred embodiment, at least a portion of the surfaces of the

first and second magnet supports are electrically non-conductive. In a preferred embodiment, at least a portion of the surfaces of the magnet, the first magnet support and the second magnet support are electrically non-conductive. In a preferred embodiment, the first end of the electrically conductive path and the second end of the electrically conductive path are electrically insulated by providing one or more of the elements of the geophone with electrically insulative surfaces. In an alternative embodiment, the magnet consists of two halves, which are connected to act magnetically as one magnet. At least a portion of the surfaces of the magnet, or one of the magnets, is made insulative with a suitable surface treatment, so that the combination of the two halves is not electrically conductive. In a preferred embodiment, one or more electrically conductive elements are electrically insulated from one or more other electrically conductive elements by providing one or more intermediate elements having electrically insulative surfaces.

A geophone has also been described that includes a housing, first and second end plates, first and second end plate supports, first and second magnet supports, a magnet, first and second resilient rings, first and second springs, first and second coil supports, and first and second coils. The housing includes a first end and a second end. The first end plate is coupled to the first end of the housing. The second end plate is coupled to the second end of the housing. The first end plate support is coupled to first end plate. The second end plate support is coupled to the second end plate. The first magnet support is coupled to the first end plate support. The second magnet support is coupled to the

second end plate support. The magnet is coupled to the first and second magnet supports. The first resilient ring is coupled to the first end plate support. The second resilient ring is coupled to the second end plate support. The first spring is coupled to the first end plate support. The second spring is coupled to the second end plate support. The first coil support is coupled to the first spring. The second coil support is coupled to the second spring. The second spring is coupled to the second end plate support. The first coil support is coupled to the first spring. The second coil support is coupled to the second spring. The first coil coupled to the first coil support. The second coil is coupled to the second coil support.

In a preferred embodiment, the geophone further includes a first retaining ring for coupling the first coil support to the first spring, and a second retaining ring for coupling the second coil support to the second spring. In a preferred embodiment, at least a portion of the surfaces of the first and second end plates are electrically non-conductive. In a preferred embodiment, an electrically insulative coating is affixed to the surfaces of the first and second end plates. In a preferred embodiment, at least a portion of the surfaces of the first and second end plate supports are electrically conductive. In a preferred embodiment, at least a portion of the surfaces of the first and second end plate supports are resistant to oxidation. In a preferred embodiment, at least a portion of the surface of the magnet is electrically non-conductive. In a preferred embodiment, at least a portion of the surface of the first magnet support is electrically non-conductive. In a preferred embodiment, at least a portion of the surface of the

second magnet support is electrically non-conductive. In a preferred embodiment, at least a portion of each surface of the first and second magnet supports is electrically non-conductive. In a preferred embodiment, at least a portion of the surfaces of the magnet and the first and second magnet supports are electrically non-conductive. In a preferred embodiment, the first and second coil supports are electrically isolated from each other.

A geophone has also been described that includes a housing, an electrically conductive terminal on one end of the housing, another electrically conductive terminal on the opposite end of the housing, a magnet mounted within the housing, and at least one coil resiliently mounted within the housing.

A method of electrically insulating at least one electrically conductive component from at least one other electrically conductive component within a geophone has also been described that includes providing at least one intermediate component between the at least one electrically conductive component and the at least one other electrically component. Wherein at least a portion of the surface of the at least one intermediate component is electrically insulative.

In a preferred embodiment, the at least one intermediate component comprises a metallic component including an electrically non-conductive surface.

A seismic acquisition system has also been described that includes at least one geophone and a controller. Each geophone includes a housing, first and second electrically conductive terminals, first and second coils, and a magnet. The first electrically conductive terminal is located on one side of the

housing. The first coil is resiliently mounted within the housing and is operably coupled to the first terminal. The second electrically conductive terminal is located on another side of the housing. The second coil is resiliently mounted within the housing and is operably coupled to the second terminal. The magnet is mounted within the housing. The controller is operably coupled to the geophone.

In a preferred embodiment, the first and second ends of the conductive path are electrically insulated from each other. In a preferred embodiment, the magnet, the first end of the conductive path, and the end of the second conductive path are electrically insulated from each other. In a preferred embodiment, the housing, the magnet, the first end of the conductive path, and the second end of the conductive path are electrically insulated from each other. In a preferred embodiment, the first end of the conductive path includes a first end plate support, a first spring, and a first coil support. In a preferred embodiment, the second end of the conductive path includes a second end plate support, a second spring, and a second coil support. In a preferred embodiment, the first end of the conductive path includes a first end plate support, a first spring, and a first coil support, and the second conductive path includes a second end plate support, a second spring, and a second coil support. In a preferred embodiment, the geophone further includes a first magnet support coupled to the housing and the magnet, and a second magnet support coupled to the housing and the magnet. In a preferred embodiment, at least a portion of the surface of the magnet is electrically non-conductive. In a preferred

embodiment, at least a portion of the surface of the first magnet support is electrically non-conductive. In a preferred embodiment, at least a portion of the surface of the second magnet support is electrically non-conductive. In a preferred embodiment, at least a portion of the surfaces of the first and second magnet supports are electrically non-conductive. In a preferred embodiment, at least a portion of the surfaces of the magnet, the first magnet support and the second magnet support are electrically non-conductive. In a preferred embodiment, the first end of the electrically conductive path and the second end of the electrically conductive path are electrically insulated by providing one or more of the elements of the geophone with electrically insulative surfaces. In a preferred embodiment, one or more electrically conductive elements are electrically insulated from one or more other electrically conductive elements by providing one or more intermediate elements having electrically insulative surfaces.

Although illustrative embodiment of the invention have been shown and described, a wide range of modification, changes and substitutions is contemplated in the in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.